

Global Climatic and Environmental Effects of the Early Permian Deglaciation

Jordan R. Noret,^{1*} Ethan L. Grossman,¹ Thomas E. Yancey¹

¹Department of Geology and Geophysics, Texas A&M University, College Station, TX 77843, USA

* Office of Undergraduate Research, 318B Jack K. Williams Administration Building, Texas A&M University, College Station, TX 77843-1112, USA

The last major deglaciation of the Earth occurred sometime during the early Permian. There was widespread glaciation during the Carboniferous and early Permian, but little or no glaciation afterwards from the middle Permian through the Mesozoic (e.g., Frakes et al., 1992; Isbell et al., 2003). Knowledge of this change from ice-house to hot-house climate and its effects on the earth's environments gives great insight into the future of our climate if current global warming continues. In this study, we will perform oxygen ($^{18}\text{O}/^{16}\text{O}$) and carbon ($^{13}\text{C}/^{12}\text{C}$) stable isotope analyses of brachiopod shells to refine records of paleotemperatures and changes in the carbon cycle during the early Permian period. This will provide greater understanding of this type of climate change, which could be analogous to current climate change, and its effects on the global environment.

INTRODUCTION

The distribution of glacial sediments has shown that the late Carboniferous was a time dominated by an ice-house climate, a climate with glaciers, and after the early Permian the climate changed to that of a hot-house, a climate without glaciers (Veevers and Powell, 1987; Frakes et al., 1992; Isbell et al., 2003). In the field of paleoclimatology, past climates have often been explained through the analyses of the isotopic anomalies in fossils of different age. These anomalies are the results of isotopic fractionation that took place in the once-living organisms and are dependent on certain environmental factors. Oxygen isotopic ratios ($^{18}\text{O}/^{16}\text{O}$) from fossils can be used as a paleotemperature record from the time in which the organism lived, thus providing a history of ancient ocean temperatures and salinity (e.g., Shackleton and Opdyke, 1973; Grossman, 1994). Carbon isotopes ($^{13}\text{C}/^{12}\text{C}$) record changes in the carbon cycle due to changes in global biomass (e.g., Popp et al., 1986; Kump and Arthur, 1999). These measurements provide details about global climate change and its environmental effects.

Under the guidance and oversight of Dr. Ethan Grossman and Dr. Thomas Yancey, Department of Geology and Geophysics, Texas A&M University, I will analyze the oxygen and carbon isotope ratios of brachiopod fossils from the early Permian period. With these data, we will determine relative global temperatures and perturbations in the carbon cycle that existed during this time. Ultimately, along with previous research from other regions of the world and from different proxies, our data will further explain the changes that occur during the deglaciation of an ice-house climate.

Current State of Knowledge

Glacial sediments and isotopic analyses of Carboniferous Period fossils show that major glaciation occurred during the mid-Carboniferous and this was accompanied by an increase in organic carbon burial (Mii et al., 2001; Grossman et al., 2007). There has been less research conducted on the Permian isotopic record than that of the Carboniferous. However, the analyses of Permian fossils and sediments have yielded the highest $\delta^{18}\text{O}$ ($^{18}\text{O}/^{16}\text{O}$ of sample versus $^{18}\text{O}/^{16}\text{O}$ of standard) values of the Paleozoic (Grossman, 1994; Grossman, 2007; Veizer, 1999). The existing data for Permian $\delta^{13}\text{C}$ ($^{13}\text{C}/^{12}\text{C}$ of sample versus $^{13}\text{C}/^{12}\text{C}$ of standard) values is highly variable and too sparse for useful interpretation of carbon cycle changes (Korte et al., 2005; Grossman, 2007).

PROJECT DESCRIPTION

The goal of this study is to use the isotopic analyses of brachiopod shells in order to understand the changes in climate associated with the early Permian deglaciation. To do this, we measure the $^{18}\text{O}/^{16}\text{O}$ and $^{13}\text{C}/^{12}\text{C}$ isotope ratios via stable isotope mass spectrometry. These isotopic ratios will then be used to determine how deglaciation affected both the climate and environment during the early Permian. High $\delta^{18}\text{O}$ values indicate that paleotemperatures were low and high $\delta^{13}\text{C}$ values correspond to increases in organic carbon sequestration (Grossman, 1994).

Aim and Expected Results of Project

It has already been demonstrated that deglaciation occurred early in the Permian, and therefore the $\delta^{18}\text{O}$ data from this study are expected to correlate to a warming of the climate. Since the carbon isotope data are sparse for this time period, we will add detail to the available isotopic data. We can then give a more refined interpretation of the timing of deglaciation and associated climatic events of the early Permian.

METHODOLOGY AND TIMELINE

Samples

There are many factors to scrutinize when using fossils for isotope paleothermometry. Most importantly, the isotopic chemistry of the samples must be the same as when the organism was buried (Grossman, 1994; Veizer, 1999). For this reason, we will use isotopic ratios of brachiopod shells, which have been shown to be resistant to chemical and physical diagenesis (Popp et al., 1986; Grossman, 1994). We will be using a collection of about 40 articulate brachiopod shells from Permian sediments in Russia. These were taken from localities throughout the Ural Mountains and are Asselian to Kungurian in age. These samples were collected by Dr. Thomas Yancey, Department of Geology and Geophysics, Texas A&M University, during September of 2005.

Sample Preparation and Analysis

The critical aspect in using stable isotope data to understand ancient global climate and environmental change is the chemical preservation of the samples studied. There are two primary methods currently used for evaluating brachiopod shells for preservation (Grossman, 2007). The one we will use involves making thin-sections of the brachiopod shells and photographing them under plane-polarized light and cathodoluminescence (CL). We will use CL microscopy to check for diagenesis. Samples that have manganese (Mn) and iron (Fe) contents have undergone some degree of diagenesis and the presence of these in the calcite structure cause it to become luminescent, therefore giving a distinctive CL signature (Popp et al., 1986; Grossman, 1994). We will use samples or parts of samples that are nonluminescent, and therefore have a well-preserved chemistry, for isotopic analysis.

For isotopic analysis we will first sample the brachiopod shells with a dental drill and then react the resulting powder with phosphoric acid using an automated carbonate reaction system. This produces CO_2 gas which is then passed to the mass spectrometer. This will give us $^{18}\text{O}/^{16}\text{O}$ and $^{13}\text{C}/^{12}\text{C}$ ratios with an average precision of 0.08‰ and 0.05‰ for $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$, respectively.

Timeline

April, 2007 – June, 2007	Reading and getting familiar with existing literature
May, 2007	Sample selection
May, 2007 – June, 2007	Training on stable isotope mass spectrometer, cathodoluminescence petrography, and sample preparation
June, 2007 – August, 2008	Sample preparation and quality determination; sample analyses; determine oxygen and carbon isotope ratios with mass spectrometer
August-November, 2008	Data interpretation; working on thesis

QUALIFICATIONS OF APPLICANT

I currently manage the X-ray Diffraction (XRD) Laboratory of the Geology and Geophysics Department. I am responsible for taking mineral samples from rocks and analyzing their composition and identifying the minerals via x-ray diffraction techniques. I am also responsible for administrative duties such as handling client relations, training, and other activities related to the management of a lab. Through these experiences I have become well acquainted with the current laboratory technicians, equipment, and procedures for several of the labs in the Geology and Geophysics Department, including the stable isotope laboratory that will be used in this study.

Scholastically, I have taken many courses that were related to the subject of this study. This includes courses covering chemical oceanography, atmospheric science, geochemistry, paleobiology, and climate change. Maintaining a 3.6 GPA, my academic background is thus well established in the subject of this study. Furthermore, I will be working under the supervision of Dr. Ethan Grossman and Dr. Thomas Yancey, well-respected scientists in this area of paleoclimatology and paleontology and who have conducted similar studies.

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